Application of CGE Modeling to Global Environmental Protection in APEC Countries

by

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Abstarct

We study the impact of introducing carbon taxes and technological innovations on the economy. The idea of imposing carbon tax has been advocated in recent years. The problem is that CO2 emissions are a global externality, but a carbon tax is levied by individual country. OECD countries have agreed that some sort of limit should be placed on CO2 emissions, but have been reluctant to adopt a carbon tax. On the other hand, we have another policy option. Energy efficiency in developing countries is relatively lower than that of developed countries. The choice of technologies for energy usage reflects a long line of decision-makings, which was governed by price structure or institutional barriers. According to the estimates, energy usage in most APEC countries is relatively inefficient as compared with the world average. Especially energy usage in Former USSR and China are tremendously inefficient. In the paper, we illustrate that technological innovation is likely to be another key element for reducing CO2 emissions.

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1. Introduction

Worldwide energy related CO2 emissions have risen steadily increased since the Industrial Revolution. Presently, atmospheric concentration of CO2 is responsible for more than half of the greenhouse effects. The reduction of CO2 emissions has thus become one of the major environmental policy objectives of most countries. At the June 1992 Earth Summit in Rio de Janeiro, more than 150 countries signed a treaty aimed at stabilizing greenhouse gases, mainly CO2. Most industrial countries have adopted national target for stabilizing CO2 emissions at 1990 levels by the year 2000. Unfortunately, CO2 emissions by OECD countries have steadily increased. The level of CO2 emissions in 2000 is estimated to be higher than that of 1990 by more than 12 percent. The rate of increase in non-OECD countries is less than that of OECD countries, which is mainly due to former USSR. If former USSR is excluded, the rate of increase in non-OECD countries is much higher than that of OECD countries. In the case of APEC Asia except for Japan, the level of CO2 emission in 1995 is higher than that of 1990 by 32 percent.

Figure 1. World CO2 Emissions by Regions

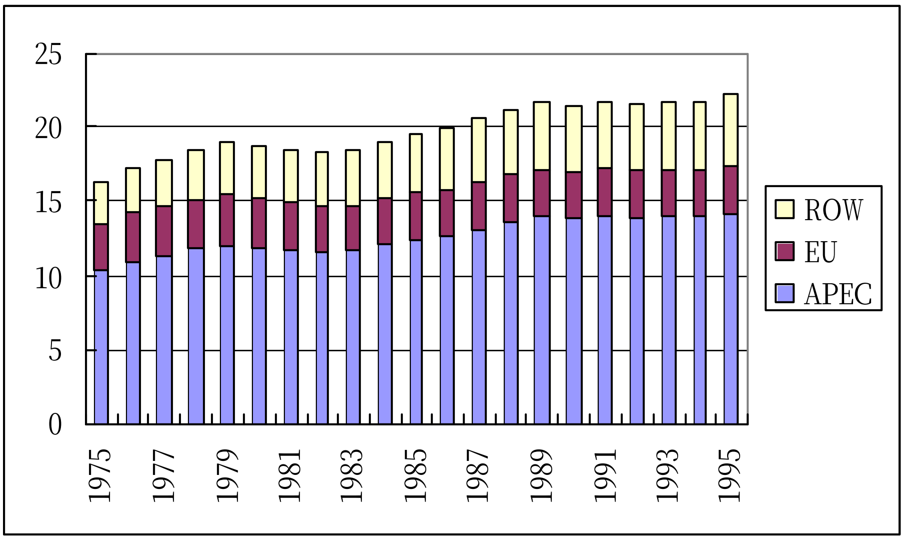


Figure 1 illustrates the CO2 emissions from fuel combustion by regions during two decades from 1975 to 1995.[1] The level of CO2 emissions has increased by 37.2 percent in APEC, 1.8 percent in EU and 69 percent in the Rest of the World during the recent two decades. As illustrated in Figure 2, the share of CO2 emissions in EU decreased from 19 percent in 1975 to 14 percent in 1995, while that of the Rest of the World increased from 17 percent in 1975 to 22 percent in 1995. On the other

[1] The Figures are based on IEA Statistics on CO2 Emissions from Fuel Combustion 1972-1995, OECD 1997.

hand, the share of APEC countries has been stable around 64 percent. These facts imply that APEC countries have been severely responsible for CO_2 emissions during the two decades.

Figure 2. The Share of CO2 Emissions by Regions in 1975 and 1995

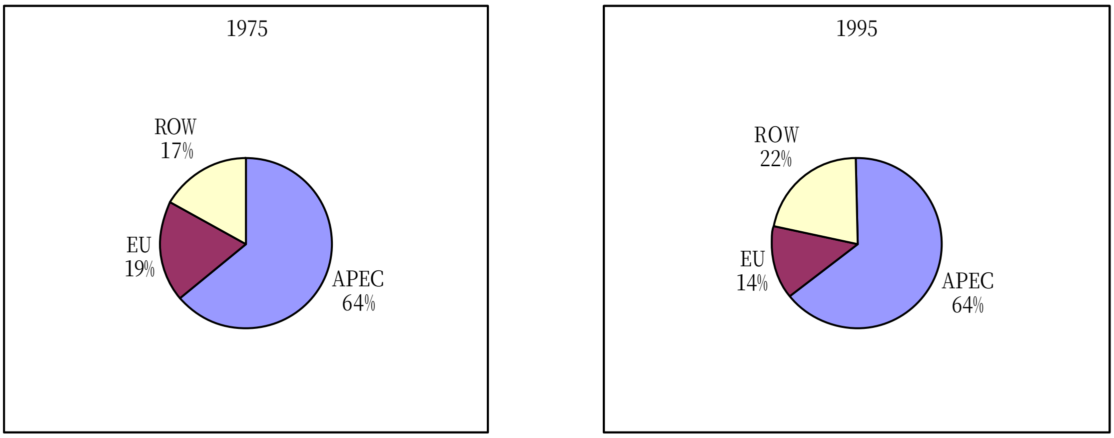


Figure 3 illustrates the CO2 emissions in APEC countries. Total share of APEC countries in the world has been stable, but the share of each countries and region has changed drastically. The share of former USSR has declined from 28 percent in 1975 to 17 percent in 1995. This is mainly due to the economy suffering from transition. GDP in Former USSR based on 1990 US$ was 945.7 billion in 1990, while it was 475.4 billion in 1995. On the other hand, the share of APEC Asia including China, NIES and ASEAN countries has increased from 13 percent in 1975 to 29 percent in 1995. These facts imply that APEC countries have to begin to contribute an increasing proportion to stabilize CO2 emissions in the world.

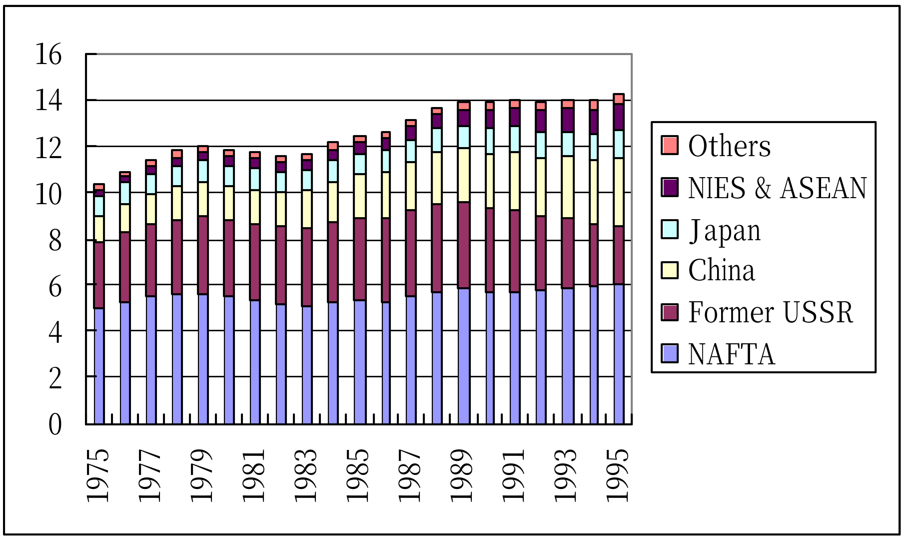


Figure 3. APEC CO2 Emissions by Regions

Figure 4. The Share of CO_2 Emissions by APEC Regions in 1975 and 1995

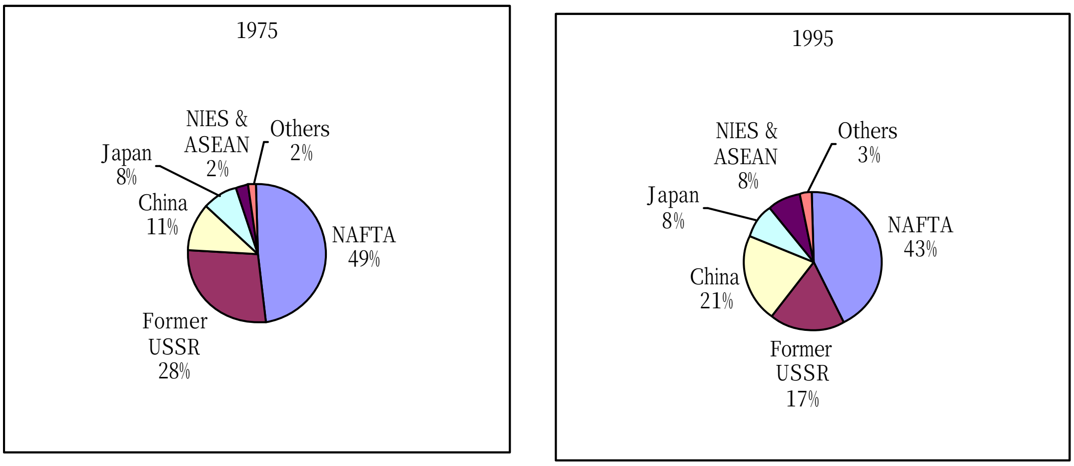


Figure 5 illustrates the ratio of CO_2 emissions to GDP based on 1990 US$ using exchange rates. The unit is expressed in kilograms of CO_2 per 1990 US$. According to the figure, energy usage in Former USSR and China are tremendously inefficient as compared with other countries. [2] Energy usage in most APEC countries is much higher than that of the world average. These facts imply that technological innovation is likely to be a key element for reducing CO_2 emissions. Therefore, it is fair to ask whether there exist some policies to promote technological innovation to save energy usage, and whether the pace of technological innovation is likely to be speeded up by policies selected. However, we will not discuss about policies for energy saving, but discuss about the impact of exogenous technological innovations on the energy usage and the economy.

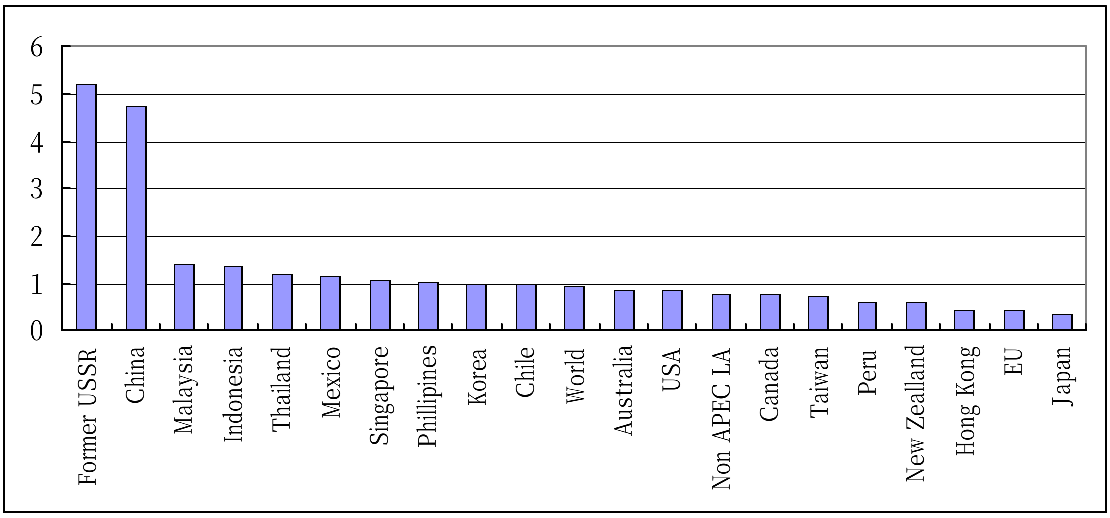
In this paper, we study the impact of introducing carbon taxes and technological innovations on the economy. The idea of imposing carbon tax has been advocated in recent years. A carbon tax would raise fossil fuel prices. As a result, demand for fossil fuel would fall. The problem is that CO_2 emissions are a global externality, but a carbon tax is levied by individual country. Some countries might not be willing to participate. OECD countries have agreed that some sort of limit should be placed on CO_2 emissions, but have been reluctant to adopt a carbon tax. It is theoretically possible for introducing a carbon tax to result in a net increase in CO_2 emissions in the world, if production in participating countries would move to nonparticipating countries, which have less efficient energy technology.

On the other hand, we have another policy option to reduce CO_2 emissions. As illustrated in Figure 5, energy efficiency in developing countries is relatively lower than that of developed

[2] IEA released another figures based on 1990 US$ using PPP, where the same basket of goods and services are used for currency conversion. According to these figures, it is 2.61 for Former USSR, 0.92 for Chine, and 0.75 for World.

countries. Of course, technologies employed in each country depend on cost minimizing behavior. That is, the choice of energy technologies reflects a long line of historical decisions, which was governed by price structure or institutional barriers. Simulation results from technological innovations in this paper advocate policies for promoting technological innovation in energy use.

Figure 5. Energy Efficiency by Countries (kilogram per 1990US$)



In this paper, we use the Global Trade Analysis Project (GTAP) Model Version 4.1.[3] The model is a multi-country and multi industry Computable General Equilibrium Model that includes a database of world input-output tables with trade and tariff matrices on 45 individual countries and regions and 50 commodities.

2. GTAP model

Table 1 and 2 shows the regional and commodity aggregation for this paper. The APEC regions were disaggregated, but non-APEC regions are aggregated. Table 3 shows factor endowments treated in the model.

According to our previous study on GTAP model, sensitivity of parameters on model properties is one essential aspect in model development. [4] There are three types of behavioral parameters in the

[3] Hertel, T.W. and M.E. Tsigas, 1997, Structure of the Standard GTAP Model, Chapter 2 in T.W. Hertel ed. Global Trade Analysis: Modeling and Applications, Cambridge University Press.

[4] K. Ban, K. Kawasaki., and M. Tstsumi, 1997, Diagnostic Analysis of CGE Modeling: the Property

GTAP model: elasticity of substitution in demand and production functions, transformation elasticity on mobility of endowment factors across sectors, flexibility of investment allocation across region. Simulation results are sensitive to Armington parameters, which reflect the assumption of imperfect substitutions. Sensitivity analysis suggests that the model properties are almost linear as concerns Armington parameters. Simulation results also depend on key assumptions on capital movement. In this paper, international capital movements are allowed in the model.

Table 1. Regional Aggregation

Abbreviation	Descriptions
ANZ	Australia and New Zealand
JPN	Japan
ASA	Indonesia, Malaysia, Philippines and Thailand
CHN	China
NIE	Korea, Singapore, Hong Kong and Taiwan
USA	United States
ONA	Canada and Mexico
SAM	Central and South America
WEU	Western Europe
FSU	Former Soviet Union
MEA	Middle East
ROW	Rest of World

Table 2. Commodity Aggregation

Abbreviation	Descriptions
AGR	Agriculture, Forestry and Fishing
COL	Coal
OIL	Oil
GAS	GAS
MNP	Mineral and Mineral Products
FDP	Food Products
PCP	Petroleum and Coal Products
CHM	Chemical Products
MTL	Metals and Metal products
OMF	Other Manufacturing
MEQ	Machinery and Equipment
EGD	Electricity and Gas Distribution
TTR	Trade and Transport
SRV	Service

of APEC Trade Liberalization, Discussion No.81, Economic Research Institutes, Economic Planning Agency.

Table 3. Endowment Aggregation

Abbreviation	Descriptions
Land	Land
UnSkLab	Unskilled labor
SkLab	Skilled labor
Capital	Capital
NatRes	Natural resource

3. Carbon Tax

It has been argued that taxing and subsidizing energy distorts consumption and production decision and have adverse consequence for local and global environment. Table 4 illustrates tax rates on fossil fuels in OECD counties in 1995. According to the table, tax rates on petroleum are relatively higher than that of coal and natural gas. Gasoline and diesel oil are highly taxed, but coal and natural gas are less taxed or not taxed. In the case of developing country, subsidy measured as the difference between domestic and world price are quite pervasive. In some case, restructuring energy pricing regime would yield rich dividend in terms of higher economic welfare and reduced CO2 emissions.

Economists have long argued that restructuring energy price regime or introducing Carbon Tax makes good for reducing CO2 emissions from the point of view of both economic and environmental sense. Unfortunately, this kind of policy has been rarely adapted. Developing countries might not be willing to participate. Even in the OECD countries, lots of people believe the possibility for introducing a carbon tax to result in a net increase in CO2 emissions in the world, because production in developed countries would move to developing countries, which have less efficient energy technology.

In this paper, we undertake three different simulations by introducing carbon tax, and evaluate their impacts on the world and national economy. In the simulations, a level of tax rate on each fossil fuel is figured out mechanically as follows. The figures are proportionate with carbon content.

- Coal 20 percent
- Petroleum 16 percent
- Natural Gas 12 percent

Table 4. Tax Rates on Fossil Fuels in OECD Country

	Coal	Petroleum									Gas	
		Gasoline			Diesel		Kerosene		Fuel		Industry	Home
		Premium	Regular	Unlead	Comm.	NonCom.	Industry	Home	Industry	Elec.		
Australia		58.1	56.8	54.6	26.5	61.2						
Austria	0		68.7	67.2	52.1	60	22.8	39.4	43.1		0	16.7
Belgium		74.7		72.3	58.5	64.8	9.5	24.9	6.5	6.5	0	21
Canada			47.5		41.3							
Denmark	25.4	72.2	70.8		46.5		8.5	64.4	18.4			20
Finland	30			74.2	57.6	65.2	17.9	32.7	22.9	22.9	9.2	25.6
France	0	82.2		80.2	67	72.4	36.4	41.1	14.2		0	16.4
Germany		76.9	78.4	76.3	63.7	68.4	22.7	32.8	14.2	27.2	14.1	19.2
Greece		74		69.9	60.8	66.7	57.5	64	26.7	26.7		
Ireland		67.2		66.3	53.2	61.1	24.4	27.7	12.1	13.9	0	11.1
Italy	0	75.8		73.2	65.2	70.7	67.5	72.7	16.5		9.6	44.5
Japan	2.9		52.8		50.6		2.9	2.9	2.9		2.9	2.9
Luxembourg		70.5	67.2	67.2	58.3	63.8	3.1	13.5	5.7			5.7
Netherlands		75.9		74.1	51.3	58.5		42	21.5		7	19.3
NewZealand		47.8	47.7		1	12	0		0		6.2	14.5
Norway		70.2		66.4	59.2	47.4	20.3	33.8	31.8			
Portugal		74		70.9	61.9	63.7	61.9	63.7	21.2	0		
Spain		69.2		67.6	59	64.6	35.3	44.2	9.5	9.5	0	15.1
Sweden		78.3		73.5	48.9	59.1	16.8	61.3	27.7	0		
Switzerland	5.6	72.6		70.8	79.2	70.4	9.8	13.7	9.5		1.3	6.8
Turkey	13	67.8		66.6	60.8			62.5	44	44	7.4	7.4
UK	0	75.9		73.6	68.4	73.1	18.9	22.9	18.8		0	7.4
US			33.3	28.6		39.7						

Source: IEA Energy Prices and Taxes

We conducted the following three simulations:

(1) carbon tax is levied in OECD such as ANZ, JPN, USA, ONA, WEU and FSU
(2) Carbon tax is levied in OECD, Former USSR, and APEC Asia such as ASA, NIE and China.
(3) Carbon tax is levied in the entire world.

Each country is supposed to levy carbon tax on both domestic produced and imported fossil fuels, but exempt carbon tax on exported fossil fuels. We use the three policy variables, to(i,r), pms(i,r,s) and txs(i,r,s), in the equations of GTAB model. to(i,r) is included in the equation which links pre- and post-tax supply prices for all industries.

ps(i,r) = to(i,r) + pm(i,r);

ps(i,r) supply price of commodity i in region r to(i,r) power of tax on output of commodity i in region r

pm(i,r) market price of commodity i in region r

tms(i,r,s) is included in the equation which links domestic and world prices.

pms(i,r,s) = tm(i,s) + tms(i,r,s) + pcif(i,r,s)

pms(i,r,s) market price by source of imported commodity i from source r to destination s

tm(i,s) power of import tax on commodity i in region s

tms(i,r,s) power of tax on imported commodity i from source r to destination s

pcif(i,r,s) world cif price of imported commodity i from source region r to destination s

txs(i,r,s) is included in the equation which links agent's and world prices.

pfob(i,r,s) = pm(i,r) - tx(i,r) - txs(i,r,s)

pfob(i,r,s) world fob price of exported commodity i from source r to destination s

tx(i,r) power of tax on exported commodity i from source r

txs(i,r,s) power of tax on exported commodity i from source r to destination s

We implement the following two new variables in the model. The first variable is quantity of total used commodity i in region r, which is defined as follows.

qdm(i,r) = (1 - SHRVIM(i,r)) * qds(i,r) + SHRVIM(i,r) * qim(i,r)

dqm(i,r) quantity of domestic sales and imports of commodity i in region r

qds(i,r) quantity of domestic sales of commodity i in region r

qim(i,r) quantity of imports of commodity i in region r

SHRVIM(i,r) share of imports of commodity i in region r

The second variable is quantity of total commodity used in the world, which is defined as follows.

quse(i) = sum(s,REG, SHRUSE(i,s) * qdm(i,s))

quse(i) quantity of total commodity i used in the world

SHRVIM(i,r) share of total commodity i used in region r

If a carbon tax were imposed, its revenue would be extremely large. Taxes distort decision making in general, and create losses for both consumer and producers. In the simulations, revenue neutral introduction of a carbon tax is supposed, where tax revenue is redistributed with no change in existing taxes. That is, all of additional tax revenue is used for government spending. In the GTAP model, allocation of the spending across sectors is determined by the Cobb-Douglas assumption of constant budget shares.

Table 5 shows the impact of carbon tax on fossil fuel use and economic welfare by regions. In the case of coal, the amount of coal used in the world declined by 1.46 percent by introducing a carbon tax in all countries in the world, while it declines by 0.89 percent by introducing a carbon tax only in advanced countries. In the case of oil, the amount of oil used in the world declined by 2.04 percent by introducing a carbon tax in all countries in the world, while it declines by 1.34 percent by introducing a carbon tax only in advanced countries. In the case of natural gas, the amount of natural gas used in the world declined by 2.06 percent by introducing a carbon tax in all countries in the world, while it declines by 1.84 percent by introducing a carbon tax only in advanced countries.

If a carbon tax is levied in OECD, Former USSR and APEC Asia, its impact depends on fossil fuels. The participation of APEC Asia in carbon tax regimes succeeds in improving worldwide CO2 emissions from coal, but fails in reducing worldwide CO2 emissions from natural gas. In the case of oil, it improves worldwide CO2 emissions slightly.

We can get some insight into "leakage" problems. Most global carbon tax regimes appear unworkable in practice, in view of difficulties of getting nations to agree on a common framework for tax. Some countries negotiate an agreement to reduce their CO2 emissions, while all other countries do not participate in the agreement. If the non-cooperating countries increase their emissions despite the abatement undertaken by the cooperating counties, leakage rises. Leakage is transmitted through trade. Suppose that the reduction in emissions is realized by a unilateral carbon tax on fossil fuels. Then the cost to domestic manufacturer using fossil fuels will rise relative to their foreign competitors, and comparative advantage will be shifted from cooperating countries to non-cooperating counties. As the non-cooperating countries produce more tradable carbon intensive goods, their CO2 emissions will rise. If the unilateral carbon tax reduces world demand for fossil fuels, and their world prices decline, then the non-cooperating countries will increase CO2 emissions even more.

According to Table 5, the amount of fossil fuels in the cooperating country decline, but those of the non-cooperating country increase. In this meaning, there exists some leakage. However, the amount of reduction in fossil fuels in the cooperating countries dominates that of the cooperating countries. As a result, even if a carbon tax is levied on only OECD and Former USSR, total amount of fossil fuels in the world declined.

In Table 5, it is shown that worldwide cooperation is more effective than that of a subset of countries in the case of coal. This result reflects that coal is cheap and plentiful fossil fuels in developing countries. In the case of China, coal is responsible for more than 85 percent of CO2 emissions. On the other hand, the cooperation among OECD and Former USSR is enough in the case of natural gas.

Table 5. Impact of Carbon Tax on Fossil Fuel Use and Economic Welfare by Region

	World	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
	Carbon tax is levied in OECD and Former USSR.												
COL	-0.89	-2.37	-0.15	0.18	0.04	0.11	-1.51	-0.07	0	-2.1	-0.54	0.81	0
OIL	-1.34	-3.15	-0.35	0.68	0.22	1.15	-3.61	-4.01	1.88	-3.52	-0.27	0.91	1.11
GAS	-1.84	-1.91	-0.34	0.19	0.14	0.47	-3.59	-2.65	0.88	-2.17	-2.02	0.32	1.01
GDP		-0.07	0	0	0	0	-0.01	-0.02	0.02	-0.03	-0.05	-0.02	0.01
EV		-214	449	85	2	169	81	-647	221	-2049	-423	-1645	39
	Carbon tax is levied in OECD, Former USSR and APEC Asia.												
COL	-1.22	-2.03	-0.11	-0.47	-1.01	-2.65	-1.5	-0.01	0.06	-2.07	-0.51	1.32	0
OIL	-1.48	-2.62	-0.24	-2.85	-0.66	-1.95	-3.53	-3.93	1.94	-3.42	-0.21	1.59	1.32
GAS	-1.83	-1.63	-0.32	-1.11	-0.37	-1.11	-3.5	-2.64	0.94	-2.14	-2.02	0.59	1.19
GDP		-0.06	0	-0.01	-0.11	-0.02	-0.01	-0.01	0.02	-0.03	-0.05	-0.01	0.02
EV		-88	817	-707	-1450	-229	661	-618	351	-1304	-333	-1599	199
	Carbon tax is levied in the entire world.												
COL	-1.46	-1.94	-0.17	-0.41	-1	-2.45	-1.53	-0.02	0.04	-1.98	-0.48	-1.51	-2.36
OIL	-2.04	-2.45	-0.19	-2.19	-0.55	-0.76	-3.17	-3.07	-1.31	-2.7	-0.01	-2.19	-1.27
GAS	-2.06	-1.55	-0.36	-0.97	-0.34	-0.67	-3.15	-2.5	-2.37	-1.93	-1.97	-1.25	-1.22
GDP		-0.05	0	0	-0.1	-0.01	-0.01	-0.01	-0.01	-0.01	-0.04	-0.22	-0.05
EV		-37	1676	-745	-1417	-178	874	-434	-414	700	-189	-3227	-2099

If carbon tax is levied, regional real GDP usually decline, but its magnitude is extremely small. GTAP also computes regional equivalent variation (EV) measures. The value in Table 5 are in 1995 $US million. In any case, both Japan and USA benefit from introducing carbon tax regimes, while fossil fuel producing countries such as ANZ, Former USSR and MEA lose. APEC Asia benefits from introducing carbon tax in advanced countries only, while they lose by introducing carbon tax in their own countries. However, fossil energy use in APEC Asia has resulted in serious air pollution including heavy smoke dust pollution and acid rain. The government in APEC Asia has begun to pay more attention to solve the environmental problems.

Table A1 to A6 in the Appendix illustrates the impact of introducing carbon tax on industrial outputs and their market prices in each country.

4. Technological Innovations

Figure 5 shows that energy efficiency in developing countries is lower than that of developed countries. Increasing energy productivity is necessary condition in order to realized sustainable development in the worldwide economy. Increasing energy productivity also yields other environmental benefits in the form of improved air and water quality. However, the choices of energy technology in each country have some microeconomic aspects. Business Firms and households have selected energy technology as a result of cost minimizing behavior. A shift from higher energy intensive technology to lower energy intensive technology would depend on the structure of relative prices. The cost effect strongly depends on the elasticity of substitution between energy and capital. In some case, higher energy prices may not necessarily increase the cost for using energy. That is, technological change is to a large extent an endogenous phenomenon in individual economy. So an additional policy can be needed for stimulating the demand for energy efficient technologies.

Despite the importance of endogenous technological innovations, we examine the impacts of exogenous productivity innovation in using fossil fuel in APEC Asia such as ASEAN countries (ASA), China (CHN) and Asia NIES countries (NIE). The shock applied to the GTAP model is a 10 percent increase in intermediate input augmenting technical change for fossil fuels, that is, af(i,j,r) in the following equation.

qf(i,j,r) = - af(i,j,r) + qo(j,r) - ESUBT(j) * [pf(i,j,r) - af(i,j,r) - ps(j,r)] ;

af(i,j,r)	intermediate input i augmenting technical change in sector j of region r
pf(i,j,r)	demand price of commodity i for firms in sector j of region r
ps(j,r)	supply price of commodity i in region r
qf(i,j,r)	quantity of composite tradable commodity i demanded by firms in Sector j region r
qo(j,r)	quantity of commodity i output in region r
ESUBT(j)	elasticity of substitution for output j

Table 5 illustrates the impact of productivity innovation in using fossil fuels in APEC Asia on the aggregated real GDP, Equivalent Variations, and the demand for commodities in each country. In the case of China, total demand for each fossil fuel decline by around 8.5 percent respectively. Table A7 in Appendix shows that technological innovation reduces the market prices of fossil fuels by 10.8 percent in the case of coal, 6.86 percent in the case of oil and 8.9 percent in the case of gas. These tendencies are observed in AEAN and Asian NIES countries. At the same time, factor prices of natural resources dec line in the entire world. It is sometimes said that if technological innovations for using fossil fuels were realized in some region in the world, the decline in demand for fossil fuels would reduce price of fossil fuels, the other countries might increase the demand for fossil fuels. As a result, CO_2 emissions might increase. Fortunately, according to the simulations, the worldwide demand for fossil fuels also decline by 2.39 percent in the case of coal, 0.85 percent of oil, and 0.35 percent in the case of gas.

Table 6 also shows that real GDP of APEC Asia increase, while that of fossil fuel producing countries such as ANZ, FSU and MEA decline slightly. From a point of equivalent variation, APEC Asia, JPN, USA and WEU benefit, while other regions lose.

Table 6. The impact of productivity innovation on demand for commodity in APEC Asia

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
GDP	-0.01	0	0.31	0.83	0.28	0	0	0	0	-0.01	-0.09	0
EV	-336	1822	1588	5917	3906	723	-311	-180	1012	-364	-3754	-365
AGR	0.22	0.02	0.06	0.18	0.09	0.03	0.05	0.01	0.01	0.07	0.01	0
COL	0.17	-0.08	-8.6	-8.38	-6.51	0	0	-0.01	0.02	0.02	0.47	-0.23
OIL	0.15	-0.06	-5.42	-8.39	-7.34	0.16	0.25	-0.07	0.23	-0.07	0	-0.51
GAS	0	0.03	-7.36	-8.56	-8.11	0.14	0.09	-0.06	0.04	0.09	-0.14	-0.01
MNP	0.05	-0.02	0.44	0.65	0.2	-0.02	-0.03	-0.02	-0.04	0.07	0.22	-0.02
FDP	0.01	0.01	0.11	0.41	0.19	0	-0.01	-0.01	0	-0.01	-0.42	0.01
PCP	0.48	0.04	1.13	0.18	0.61	0.4	0.23	0.14	0.34	0.02	0.17	-0.02
CHM	0.11	0.03	0.11	0.18	0	0.02	0.08	0.04	-0.01	0.08	0.29	0.04
MTL	0.17	-0.03	0.15	0.53	-0.33	0.01	0.07	0.02	-0.02	0.1	0.56	0.1
OMF	0.03	0.03	0.06	-0.33	0.06	0.01	0.05	0.03	0.02	0.03	-0.22	0.1
MEQ	-0.05	0.02	0.14	0.68	0.01	0	0.05	0.01	0.01	-0.04	-1.35	0.17
EGD	0.12	0.03	0.44	0.16	0.22	0.13	0.04	0	0.07	0.04	0.08	0.02
TTR	-0.03	0.01	0.25	0.35	0.14	0	-0.02	-0.01	0	-0.03	-0.6	0
SRV	-0.08	0.02	0.31	1.11	0.34	-0.01	-0.05	-0.02	0	-0.06	-1.01	0

5. Summary and Policy Implications

In the paper, we study the impact of introducing carbon taxes and technological innovations on the economy. The idea of imposing carbon tax has been advocated in recent years. The problem is that CO2 emissions are a global externality, but a carbon tax is levied by individual country. Some countries might not be willing to participate. OECD countries have agreed that some sort of limit should be placed on CO2 emissions, but have been reluctant to adopt a carbon tax. On the other hand, we have another policy option. Energy efficiency in developing countries is relatively lower than that of developed countries. The choice of technologies for energy usage reflects a long line of decision-makings, which was governed by price structure or institutional barriers. According to the estimates, energy usage in most APEC countries is relatively inefficient as compared with the world average. Especially energy usage in Former USSR and China are tremendously inefficient. In the paper, we illustrate that technological innovation is likely to be another key element for reducing CO2 emissions.

In this paper, we use the GTAP Model to evaluate the impact of policy options to reduce CO2 emissions. Economists recommend introducing Carbon Tax, but it has been rarely adapted. Developing countries might not be willing to participate. Even in the OECD countries, it is sometime believed that introducing a carbon tax in developed countries may increase the world-wide

CO2 emissions, because production in developed countries would move to developing countries, where less efficient energy technology is used.

We undertake simulations to evaluate the impact of introducing carbon tax with or without worldwide cooperation. According to the simulation results, even if a carbon tax on fossil fuels coal is levied only in the developed countries, the amount of CO2 emissions will be reduced. This fact implies that even if the non-cooperating countries increase their emissions despite the abatement undertaken by the cooperating counties, and leakage rises as a result, CO2 emissions will decline in the world. However, imposing carbon tax on coal in all countries in the world is more effective than that of only developed countries. Specially, the participation of APEC Asia in carbon tax regimes succeeds in improving worldwide CO2 emissions from coal.

Energy efficiency in APEC Asia and former USSR is lower than that of other countries. Despite the importance of endogenous technological innovations, we examine the impacts of exogenous productivity innovation in using fossil fuel in APEC Asia. The shoc k applied to the GTAP model is a 10 percent increase in intermediate input augmenting technical change for fossil fuels. Simulation results illustrate that productivity innovations in using fossil fuels in APEC Asia improve not only the amount of CO2 emissions, but also the aggregated real GDP and Equivalent Variations (EV).

The government in APEC Asia has begun to pay more attention to solve the environmental problems. Because the fossil energy use in APEC Asia has resulted in serious air pollution including heavy smoke dust pollution and acid rain. According to the simulations in this paper, we can propose two policy options. The one is a carbon tax and the other is a technological innovation. Among a large number of developing countries, huge subsidies for fossil fuels result in a huge discrepancy between domestic prices and world prices. Subsidizing distorts consumption and production decisions and adverse consequences not only for government revenue, but also for the protection of local environment problems. Fossil energy use in APEC Asia has resulted in serious air pollution including heavy smoke dust pollution and acid rain. Taking these facts into account, we can propose imposing carbon tax for the developed APEC countries, and removing subsidies for the developing APEC countries. As for the other policy option, technology transfer in the filed of fossil energy use among APEC region is also recommended. Its impact on reducing CO2 emissions is reliable, because energy efficiency in developing APEC countries are relatively lower that that of world. Moreover, economic and political cost for implementing policy might be lower than that of carbon tax.

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Appendix

Table A1. The impact on outputs: carbon tax levied in OECD and Former USSR

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
AGR	0.09	0.03	0	-0.01	-0.01	0.05	0.12	-0.1	0	0.72	0.16	-0.04
COL	-0.8	-0.9	0.92	0.36	0.43	-1.97	-0.87	0.96	-2.83	-0.78	0.88	0.75
OIL	-1.85	-1.8	-0.58	-0.35	-0.99	-2.58	-2.46	-0.6	-2.91	-1.65	-0.42	-0.77
GAS	-1.47	-1.03	-0.34	-0.14	-0.5	-3.45	-2.54	-0.11	-2.15	-1.2	-0.13	-0.46
MNP	0.08	0.02	0.21	0.04	0.1	-0.14	0.51	-0.06	-0.2	0.26	1.21	0.12
FDP	0.07	0.01	-0.04	-0.03	-0.01	0.03	0.12	-0.09	0.01	0.63	0.02	-0.07
PCP	-4	-0.36	0.96	0.27	1.61	-5.23	-4.29	3.75	-3.72	-0.05	1.48	2.19
CHM	0.38	-0.37	0.53	0.3	0.46	-0.27	-1	0.14	0.17	-3.67	1.01	0.32
MTL	-0.42	-0.09	0.24	-0.03	0.11	-0.07	0.55	-0.15	-0.06	1.1	0.85	-0.01
OMF	0.31	0.01	-0.09	-0.16	-0.15	0.03	0.51	-0.16	0.07	0.87	0.45	-0.22
MEQ	0.28	-0.03	-0.19	-0.18	-0.33	0.09	0.72	-0.23	0.08	0.17	0.82	-0.22
EGD	-0.79	-0.23	0.02	0.03	0.06	-1.52	-0.22	0.01	-0.99	-0.53	0.06	0.07
TTR	0.02	0.04	-0.03	-0.01	-0.09	0.05	0.07	-0.06	0.01	0.34	0.08	-0.07
SRV	0.06	0.04	0.07	0.07	0.06	0.12	0.02	0.09	0.07	0.03	-0.2	0.1

Table A2. The impact on market prices: carbon tax levied in OECD and Former USSR

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
Land	0.24	0.33	0.38	0.33	0.34	0.34	0.38	0.08	0.14	2.4	0.72	0.3
UnSk	-0.25	0.18	0.41	0.41	0.43	0.1	-0.21	0.63	0.15	-1.82	-0.04	0.52
SkLab	-0.24	0.18	0.44	0.43	0.44	0.13	-0.23	0.68	0.15	-1.92	-0.2	0.57
Capit	-0.33	0.16	0.41	0.4	0.46	0.02	-0.36	0.64	0.1	-2.1	-0.15	0.55
NatRe	-7.26	0.06	-1.24	1.32	0.5	-16.9	-14.4	-2.46	-13.3	-10.3	-2.98	-2.29
AGR	0.36	0.33	0.4	0.41	0.4	0.37	0.38	0.52	0.41	-0.03	0	0.45
COL	23.31	23.35	2.28	1.24	1.44	24.7	23.63	2.6	24.7	23.53	1.79	2.07
OIL	14.93	15.56	-0.73	-0.28	-0.79	13.78	13.76	-0.74	14.52	14.8	-1.04	-1.13
GAS	11.52	11.87	-0.31	0.1	-0.3	8.85	8.62	0.28	10.61	9.69	-0.45	-0.5
MNP	0.43	0.45	0.4	0.47	0.42	0.67	0.31	0.59	0.64	0.42	-0.02	0.48
FDP	0.31	0.34	0.39	0.43	0.41	0.33	0.19	0.57	0.37	-0.35	0	0.47
PCP	11.2	1.34	-0.32	-0.08	-0.16	9.79	11.11	-0.11	7.45	2.33	-0.65	-0.33
CHM	0.48	1.29	0.44	0.48	0.49	0.99	1.39	0.56	0.59	3.64	0.05	0.44
MTL	0.72	0.62	0.43	0.49	0.43	0.64	0.41	0.63	0.51	0.1	0.08	0.49
OMF	0.19	0.38	0.41	0.44	0.44	0.4	0.22	0.59	0.36	-0.35	0.04	0.49
MEQ	0.2	0.38	0.4	0.44	0.43	0.32	0.2	0.58	0.32	-0.54	0.07	0.48
EGD	3.4	1.04	0.27	0.56	0.5	4.22	1.34	0.6	3.33	3.63	-0.22	0.45
TTR	0.18	0.27	0.39	0.4	0.43	0.33	0.17	0.61	0.35	-0.79	-0.08	0.49
SRV	-0.02	0.29	0.4	0.43	0.42	0.23	-0.03	0.62	0.26	-1.15	-0.05	0.5

Table A3. The impact on outputs: carbon tax levied in OECD, Former USSR and APEC

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
AGR	-0.14	-0.02	0.1	0.55	0.07	-0.04	0.04	-0.15	-0.06	0.6	0.07	-0.06
COL	-0.46	-0.57	-0.48	-1.22	-4.22	-1.77	-0.51	1.22	-2.65	-0.6	1.02	0.97
OIL	-2	-1.93	-2.02	-1.17	-4.98	-2.57	-2.45	-0.62	-2.94	-1.7	-0.54	-0.79
GAS	-1.37	-0.95	-1.12	-0.59	-3.45	-3.37	-2.46	-0.03	-2.1	-1.18	-0.09	-0.37
MNP	0.41	0.1	-0.5	-1.05	-0.91	-0.04	0.75	0.06	-0.07	0.29	1.28	0.3
FDP	-0.07	0	0.1	0.53	0.04	0.01	0.12	-0.12	-0.01	0.55	-0.03	-0.09
PCP	-3.28	0.46	-3.37	-0.74	-2.7	-5.09	-4.2	3.88	-3.6	0.02	2.51	2.57
CHM	0.36	-0.35	0.7	0.15	0.18	-0.25	-0.94	0.14	0.2	-3.69	1.01	0.35
MTL	-0.22	-0.02	-0.18	-1.45	0.12	-0.02	0.74	-0.06	0.05	1.22	0.93	0.11
OMF	0.01	-0.11	0.32	2.12	-0.01	-0.1	0.24	-0.28	-0.08	0.68	0.17	-0.39
MEQ	0.11	-0.15	0.88	0.42	0.22	0.04	0.68	-0.25	0.02	0.12	0.66	-0.25
EGD	-0.77	-0.23	-0.33	-0.68	-0.14	-1.53	-0.21	0.02	-0.99	-0.52	0.08	0.08
TTR	0	0.04	0.01	0.22	0.12	0.04	0.07	-0.07	0	0.32	0.05	-0.08
SRV	0.1	0.07	-0.12	-0.87	-0.03	0.14	0.06	0.12	0.09	0.05	-0.13	0.13

Table A4. The impact on market prices: carbon tax levied in OECD, Former USSR and APEC

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
Land	-1.21	-0.16	0.12	0.04	-0.05	-0.4	-0.29	-0.4	-0.39	1.53	0.14	-0.09
UnSk	-0.43	-0.02	-0.61	-3.14	-0.58	-0.12	-0.47	0.42	-0.07	-1.98	-0.14	0.29
SkLab	-0.4	-0.02	-0.7	-3.75	-0.59	-0.09	-0.48	0.5	-0.06	-2.06	-0.26	0.37
Capit	-0.5	-0.03	-0.6	-3.47	-0.62	-0.21	-0.61	0.43	-0.12	-2.25	-0.25	0.33
NatRe	-6.62	-0.33	-6.88	-9.96	-2.85	-16.7	-14.4	-2.7	-13.3	-10.3	-3.81	-2.25
AGR	0.04	0.09	-0.07	-1.49	-0.11	0.07	0.06	0.27	0.16	-0.3	-0.17	0.19
COL	23.9	23.85	24	25.23	20.05	24.9	24.15	2.95	24.84	23.78	1.96	2.33
OIL	14.43	15.08	14.47	15.2	15.59	13.53	13.49	-0.98	14.23	14.53	-1.4	-1.39
GAS	11.56	11.81	11.65	12	12.2	8.76	8.5	0.15	10.47	9.58	-0.48	-0.55
MNP	0.27	0.26	0.66	1.34	1.22	0.45	0.07	0.39	0.42	0.27	-0.16	0.29
FDP	0.08	0.11	-0.08	-1	-0.05	0.09	-0.08	0.34	0.14	-0.56	-0.16	0.23
PCP	11.03	1.14	8.96	9.23	7.73	9.57	10.85	-0.34	7.21	2.18	-0.91	-0.54
CHM	0.31	1.09	0.22	0.72	0.55	0.77	1.15	0.35	0.38	3.5	-0.11	0.24
MTL	0.56	0.44	0.51	1.56	0.45	0.42	0.18	0.43	0.3	-0.04	-0.06	0.3
OMF	-0.03	0.16	-0.06	-0.59	0	0.16	-0.04	0.38	0.13	-0.52	-0.14	0.26
MEQ	0.01	0.18	-0.1	-0.32	0.02	0.09	-0.04	0.37	0.1	-0.7	-0.08	0.27
EGD	3.27	0.84	3.36	6.25	2.05	4.03	1.1	0.4	3.14	3.53	-0.36	0.26
TTR	0.01	0.07	-0.02	-1.14	-0.12	0.1	-0.09	0.4	0.13	-0.95	-0.22	0.28
SRV	-0.19	0.09	-0.03	-0.9	-0.09	0.01	-0.28	0.42	0.04	-1.3	-0.18	0.29

Table A5. The impact on outputs: carbon tax levied in the entire world

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
AGR	-0.39	-0.11	0.04	0.51	0.04	-0.21	-0.13	0.04	-0.32	0.4	1.26	0.18
COL	-0.44	-0.61	-0.45	-1.2	-4.21	-1.77	-0.5	-0.35	-2.59	-0.59	0.29	-1.04
OIL	-1.97	-2	-1.93	-1.13	-5.04	-2.4	-2.22	-2.87	-2.77	-1.67	-1.12	-2.73
GAS	-1.29	-0.93	-0.99	-0.51	-3.16	-3.04	-2.08	-5.1	-2.02	-1.27	-1.29	-1.77
MNP	0.26	0.04	-0.56	-1.06	-0.95	-0.16	0.58	0.32	-0.18	0.17	4.36	-0.05
FDP	-0.22	-0.02	0	0.5	0.03	-0.05	0.07	0.06	-0.14	0.46	0.96	0.22
PCP	-3.04	1.23	-2.33	-0.59	-1	-4.48	-3.28	-1.39	-2.68	0.24	-2.71	-1.32
CHM	0.35	-0.39	0.83	0.17	0.19	-0.27	-1.05	-0.35	0.25	-3.63	2.59	-0.13
MTL	-0.19	-0.11	-0.04	-1.4	0.2	-0.04	0.72	0.22	0.18	1.15	3.9	-0.56
OMF	-0.06	-0.19	0.14	1.97	-0.22	-0.21	0	0.06	-0.26	0.46	3.55	0.62
MEQ	0.18	-0.28	1.09	0.49	0.27	0.02	0.72	0.33	-0.02	0.13	4.43	0.64
EGD	-0.78	-0.25	-0.34	-0.66	-0.12	-1.57	-0.23	-0.09	-0.98	-0.52	-0.05	-0.36
TTR	-0.02	0.01	-0.04	0.21	0.04	0.02	0.04	-0.03	-0.05	0.28	0.81	0.24
SRV	0.14	0.14	-0.1	-0.82	-0.01	0.17	0.13	0.12	0.14	0.09	-1.09	-0.1

Table A6. The impact on market prices: carbon tax levied in the entire world

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
Land	-2.71	-0.68	-0.57	-0.44	-0.55	-1.58	-1.43	-0.53	-1.9	0.16	1.72	-0.42
UnSk	-0.63	-0.09	-0.9	-3.4	-0.83	-0.31	-0.68	-0.74	-0.31	-2.13	-4.15	-1.48
SkLab	-0.57	-0.08	-0.95	-3.96	-0.83	-0.27	-0.66	-0.7	-0.29	-2.17	-5.01	-1.58
Capit	-0.68	-0.09	-0.86	-3.69	-0.84	-0.39	-0.79	-0.79	-0.34	-2.38	-4.61	-1.63
NatRe	-6.75	-0.79	-6.9	-10.1	-3.24	-15.9	-13.3	-15.5	-13.3	-10.7	-12	-14.4
AGR	-0.31	-0.05	-0.48	-1.79	-0.43	-0.24	-0.27	-0.42	-0.19	-0.67	-2.3	-0.76
COL	23.7	23.67	23.8	24.99	19.8	24.69	23.98	24	24.69	23.59	22.66	22.72
OIL	14.28	14.83	14.36	15.04	15.26	13.67	13.72	14.86	14.31	14.41	13.96	14.58
GAS	11.51	11.77	11.64	11.92	12.25	9.25	8.96	17.13	10.39	9.24	11.59	10.88
MNP	0.07	0.18	0.41	1.11	0.99	0.27	-0.11	-0.12	0.19	0.1	-1.82	0.07
FDP	-0.18	-0.02	-0.4	-1.27	-0.34	-0.14	-0.32	-0.41	-0.14	-0.82	-2.37	-0.65
PCP	10.87	1.07	8.76	9.04	7.49	9.7	11	8.35	7.07	2.02	8.09	7.8
CHM	0.11	1.03	-0.04	0.49	0.34	0.6	1.04	0.75	0.15	3.27	-1.24	0.34
MTL	0.37	0.35	0.28	1.33	0.23	0.24	-0.01	0.08	0.06	-0.2	-1.93	0.36
OMF	-0.25	0.07	-0.33	-0.84	-0.23	-0.03	-0.23	-0.31	-0.12	-0.71	-2.45	-0.6
MEQ	-0.18	0.1	-0.32	-0.55	-0.19	-0.09	-0.23	-0.29	-0.14	-0.87	-2.25	-0.54
EGD	3.09	0.78	3.18	6.03	1.87	3.92	0.97	0.04	2.94	3.36	-0.79	1.95
TTR	-0.19	-0.02	-0.27	-1.37	-0.35	-0.08	-0.26	-0.27	-0.11	-1.11	-2.72	-0.81
SRV	-0.38	0.01	-0.27	-1.13	-0.32	-0.18	-0.46	-0.52	-0.19	-1.45	-3.18	-0.85

Table A7. The impact on outputs: technological innovation in APEC Asia

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
AGR	0.36	0.02	-0.02	-0.1	-0.03	0.07	0.1	0.04	0.03	0.16	0.67	0.01
COL	-1.94	-1.75	-2.96	-6.14	-1.34	-0.88	-1.89	-1.28	-0.7	-0.84	-0.01	-1.11
OIL	-1.28	-1.49	-2.15	-4.52	-1.77	-0.64	-0.74	-0.69	-0.86	-0.85	-0.45	-0.87
GAS	-1.04	-1.29	-1.96	-5.3	-2.61	0.01	0	-0.35	-0.21	-0.15	-0.48	-0.45
MNP	-0.05	-0.13	0.59	1.02	0.53	-0.16	-0.24	-0.13	-0.22	0.1	2.76	-0.07
FDP	0.25	0.02	-0.02	-0.04	0.08	0.01	0.01	0.01	0	0.11	0.31	0.01
PCP	0.15	-0.81	3.9	1.08	2.68	0.21	0.27	0.05	0.22	-0.09	0.18	-0.08
CHM	0.17	0.02	-0.07	0.56	-0.03	-0.04	0.09	0.06	-0.09	0.26	1.78	0.06
MTL	0.27	-0.14	0.41	1.43	-0.41	-0.05	-0.03	-0.01	-0.1	0.27	1.97	0.13
OMF	0.38	0.07	-0.16	-1.4	-0.3	0.09	0.29	0.12	0.1	0.27	1.83	0.18
MEQ	0.48	-0.03	-0.52	-0.08	-0.69	0.05	0.27	0.11	0.1	0.18	2.8	0.21
EGD	0.12	0.03	0.45	0.28	0.06	0.13	0.03	0	0.07	0.04	0.08	0.02
TTR	0.06	0	0.15	0.13	-0.13	0	0	0.01	-0.01	0.04	0.39	0.01
SRV	-0.06	0.02	0.28	0.99	0.25	-0.01	-0.04	-0.02	0	-0.04	-0.82	0.01
CGDS	-0.17	0.04	0.45	1.99	0.57	-0.03	-0.07	-0.03	-0.03	-0.08	-3.04	0.07

Table A8. The impact on market prices: technological innovation in APEC Asia

	ANZ	JPN	ASA	CHN	NIE	USA	ONA	SAM	WEU	FSU	MEA	ROW
Land	1.83	0.22	0.36	2.03	0.52	0.41	0.53	0.19	0.12	0.83	1.55	0.08
UnSk	-0.1	0.12	0.53	2.62	0.71	0.02	0.01	-0.02	-0.02	-0.12	-1.67	0.03
SkLab	-0.15	0.12	0.62	3.13	0.78	0.02	-0.01	-0.04	-0.02	-0.16	-2.25	0.03
Capit	-0.17	0.12	0.53	2.68	0.76	0.01	-0.03	-0.04	-0.02	-0.18	-1.83	0
NatRe	-8.5	-0.16	-8.15	-26.3	-0.4	-2.96	-3.91	-3.94	-3.31	-3.18	-4.93	-5.26
AGR	0.01	0.1	0.24	1.65	0.4	0.04	0.03	-0.02	-0.04	-0.03	-1.34	-0.02
COL	-3.76	-3.09	-5.2	-10.8	-3.76	-1.94	-3.52	-2.5	-1.63	-1.86	-1.57	-2.21
OIL	-2.65	-2.7	-3.77	-6.86	-3.25	-1.25	-1.44	-1.57	-1.76	-1.85	-2.7	-1.9
GAS	-2.32	-2.36	-3.87	-8.9	-4.66	0.02	-0.05	-0.66	-0.52	-0.51	-2.94	-1.05
MNP	-0.24	0.05	-0.46	-1.06	-0.62	-0.05	-0.07	-0.09	-0.07	-0.26	-1.46	-0.17
FDP	-0.12	0.08	0.16	1.04	0.29	0.01	-0.02	-0.04	-0.04	-0.12	-1.35	-0.06
PCP	-2.07	-0.15	-7.56	-9.2	-5.97	-0.81	-1.14	-0.94	-0.91	-0.45	-2.3	-1.12
CHM	-0.22	-0.15	-0.08	-0.63	-0.18	-0.07	-0.15	-0.17	-0.07	-0.35	-1.31	-0.2
MTL	-0.28	0.01	-0.3	-1.2	-0.13	-0.04	-0.07	-0.11	-0.06	-0.24	-1.22	-0.19
OMF	-0.13	0.07	0.13	0.56	0.22	-0.01	-0.03	-0.06	-0.04	-0.18	-1.26	-0.07
MEQ	-0.14	0.06	0.17	0.28	0.19	0	-0.03	-0.06	-0.03	-0.19	-1.14	-0.08
EGD	-0.77	-0.07	-2.76	-4.97	-1.12	-0.33	-0.19	-0.1	-0.27	-0.47	-1.93	-0.37
TTR	-0.19	0.09	0.05	0.84	0.34	-0.01	-0.05	-0.07	-0.04	-0.19	-1.62	-0.07
SRV	-0.16	0.09	0.07	0.73	0.32	0	-0.03	-0.05	-0.03	-0.18	-1.58	-0.06